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THE IMPACT OF DIGITAL LITERACY AND DISASTER MITIGATION UNDERSTANDING ON COMPUTATIONAL AND SPATIAL THINKING ABILITY IN UPPER SECONDARY SCHOOL STUDENTS

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Abstract. *Computational thinking and spatial thinking ability play a critical role in enabling students to respond effectively to disasters. However, limited research has examined the impact of digital literacy, disaster education, and cognitive skills in secondary school students. This study aims to assess the impact of digital literacy and disaster mitigation understanding on the development of computational and spatial thinking ability in upper secondary school students. A quantitative research approach was employed using Structural Equation Modeling to analyze the impact of the variables. The research participants in this study consisted of 258 students enrolled in two upper secondary schools, namely Public Senior High School 21 Makassar and Public Senior High School 4 Barru. Data were collected through questionnaires and performance-based tests. The results revealed that digital literacy positively impacted computational thinking and spatial thinking. Similarly, disaster mitigation understanding positively impacted computational thinking and spatial thinking. Moreover, computational thinking demonstrated a moderate positive impact on spatial thinking, indicating a strong interaction between these cognitive domains. These findings suggest that students with higher digital literacy and disaster knowledge exhibit stronger problem-solving and spatial reasoning skills, which are crucial for disaster preparedness and risk mitigation.*

Keywords: *digital literacy, disaster mitigation understanding, computational thinking, spatial thinking, upper secondary school*

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Introduction

The integration of digital literacy into education has gained significant attention in recent years due to its potential to enhance students' cognitive skills, particularly computational and spatial thinking. These skills are essential for preparing students to address 21st-century challenges, where technology and data-driven problem-solving play a fundamental role. Computational thinking, which involves problem decomposition, pattern recognition, and algorithmic design, enables students to approach complex problems systematically (Jacob & Warschauer, 2018; Santosa, 2024; Üzümcü & Bay, 2020; Verawati, 2023). In parallel, spatial thinking helps students visualize and interpret spatial relationships between objects, allowing them to better engage with real-world phenomena (Park & Kwon, 2022; Tsai & Wang, 2021). Disaster mitigation, a multifaceted field, requires both spatial understanding and problem-solving abilities, which can be effectively enhanced through these cognitive skills.

Research has emphasized the importance of disaster mitigation education for secondary school students, as they are at a critical developmental stage where such knowledge can impact their behavior and decision-making. Previous studies have found that students equipped with disaster mitigation skills are more likely to engage in risk-reduction behaviors and demonstrate heightened awareness of environmental threats (Atmojo et al., 2018; Ayub et al., 2022; Gadeng et al., 2022; Perbawasari et al., 2020; Rofiah et al., 2021). Comprehensive disaster education curricula implemented in schools have been shown to improve students' preparedness and understanding of potential environmental threats (Gadeng et al., 2022; Rofiah et al., 2021). For instance, integrating disaster literacy into school programs has significantly enhanced students' understanding of disaster risks and their ability to respond

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appropriately (Logayah, 2023). However, despite these advancements, limited empirical research has explored the interaction between digital literacy and disaster mitigation education in fostering computational and spatial thinking ability, particularly in secondary school contexts.

The primary issue addressed in this study is the limited understanding of how digital literacy and disaster mitigation education collectively impact computational and spatial thinking ability among secondary school students. A comprehensive examination of these relationships is necessary to uncover mechanisms by which digital literacy and disaster education support critical cognitive skills, providing insights for improving curriculum design.

Existing research has highlighted the role of digital literacy in enhancing cognitive abilities, particularly computational thinking, which is a key skill for navigating the digital age. Digital literacy encompasses a range of competencies, including the ability to effectively use digital tools, critically evaluate information, and engage in problem-solving processes foundational to computational thinking (Koçak & Göksu, 2020; Nurwahidah et al., 2021; Tian, 2023). Students with strong digital literacy skills are better equipped to analyze problems and design effective solutions using technology (Cintamulya et al., 2023; Gümüş, 2024; Pratiwi et al., 2023). Digital literacy has been found to improve engagement and enable students to approach problems algorithmically, further enhancing their computational thinking ability (Kesici, 2022; Cintamulya et al., 2023; Leuwol, 2023).

Spatial thinking is also crucial in disaster mitigation education, as it enables students to analyze geographic and environmental data necessary for predicting and responding to natural hazards. Spatial reasoning allows students to visualize data related to hazards, vulnerabilities, and available resources, thereby enhancing disaster preparedness and response strategies. Previous studies have indicated that spatial thinking ability enables students to effectively utilize tools like Geographic Information Systems (GIS) and spatial analysis techniques to assess risks and develop mitigation strategies (Wahyu et al., 2023; Purwanto et al., 2023). For instance, students trained in spatial analysis have demonstrated improved abilities to assess flood risks and devise spatial planning policies to mitigate such hazards. Disaster mitigation education inherently involves the interpretation of spatial data, fostering critical thinking and problem-solving abilities essential for reducing disaster impacts.

While previous research has examined digital literacy and disaster mitigation separately, little research has examined their combined impact on computational and spatial thinking ability, especially in secondary education. For example, GIS tools have been found to help students analyze spatial data in disaster education contexts, enhancing their understanding of disaster dynamics (Logayah, 2023). Similarly, digital storytelling projects that integrate disaster scenarios have been shown to encourage critical thinking and problem-solving, fostering both computational and spatial thinking ability (Vice et al., 2024). However, there remains a gap in the literature regarding the comprehensive effects of integrating digital literacy and disaster mitigation education on these cognitive skills.

This study addressed this research gap by assessing the impact of digital literacy and disaster mitigation education on computational and spatial thinking ability in upper secondary school students. The research hypotheses were as follows:

H_1: Disaster mitigation understanding impacts computational thinking ability
H_2: Disaster mitigation understanding impacts spatial thinking ability
H_3: Digital literacy impacts computational thinking ability
H_4: Digital literacy impacts spatial thinking ability
H_5: Computational thinking ability impacts spatial thinking ability

The novelty of this research lies in its interdisciplinary approach, combining digital literacy and disaster education to examine their collective impact on cognitive development. This research is justified by the need for a comprehensive understanding of how these domains can be integrated into secondary education curricula to foster essential cognitive skills. Developing computational and spatial thinking abilities is crucial for problem-solving and decision-making in complex scenarios.

Research Methodology

Design

This study employed a quantitative research approach to assessing the impact of digital literacy, disaster mitigation understanding on computational and spatial thinking in upper secondary school students. A correlational research design incorporating SEM was utilized for data analysis.

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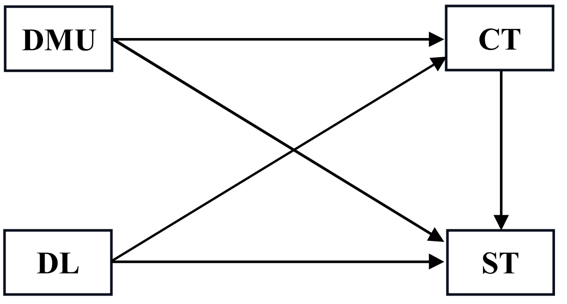
Figure 1
SEM Model Diagram



This design facilitates the examination of direct and indirect impacts between digital literacy, disaster mitigation understanding, and computational and spatial thinking ability. Cross-sectional data were collected through a survey instrument, and SEM was used to evaluate measurement validity and structural pathways among the variables. This design is in line with the research designs of Mariam et al (2021) and Matsuno and Hirano (2021), which demonstrate the efficacy of SEM in educational research, especially in analyzing the interaction between educational factors and student learning outcomes.

Participants

The participants of this study consisted of upper secondary school students from schools that have officially integrated digital literacy and disaster mitigation education into their curriculum. The selection of participants followed a stratified random sampling technique to ensure that the sample was sufficiently representative of students in different grade levels while maintaining diversity in their exposure to digital literacy and disaster mitigation education.

The research participants in this study consisted of 258 students enrolled in upper secondary schools, namely Public Senior High School 21 Makassar and Public Senior High School 4 Barru. Since both schools have formally integrated digital literacy and disaster mitigation education into their curricula, all students already met the foundational criteria for inclusion in this study. The sample size of 258 students was based on students who voluntarily agreed to participate in the study after receiving informed consent. The distribution of participants was based on their grade level, to ensure a representative sampling of grades X, XI, and XII (Table 1). This stratification allows for potential variations in digital literacy, disaster mitigation understanding, and cognitive skill development across different academic levels.

Table 1
Research Sample from 3 Different Grade Levels

Item	Grade	Total	%
Male Students	X	39	15.12
	XI	41	15.89
	XII	34	13.18
Female Students	X	43	16.67
	XI	54	20.92
	XII	47	18.22
Total		258	100

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Research Instruments

The research instruments consisted of a structured questionnaire and performance-based tests designed to measure students' competencies in digital literacy, disaster mitigation understanding, computational thinking, and spatial thinking ability. The development of these instruments was based on an extensive literature review and expert consultation to ensure content validity and reliability.

The structured questionnaire was employed to measure students' digital literacy and understanding of disaster mitigation. This questionnaire consisted of two main sections. The first section focused on digital literacy, meanwhile the second section measured disaster mitigation understanding. The statements of each indicator in the structured questionnaire are summarized in Table 2.

Each section included six items scored on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree). The questionnaire was pilot-tested with 50 students to evaluate its clarity and reliability. Expert feedback from three senior academics specializing in disaster education and digital literacy was incorporated to refine the instrument. Reliability was established using Cronbach's Alpha, with all constructs exceeding the recommended threshold of .70, confirming internal consistency.

A performance-based test was used to measure students' computational and spatial thinking abilities. The test consisted of 16 open-ended questions, which were divided equally between the computational thinking and spatial thinking assessments. The computational thinking component consisted of eight questions that tested students' ability to decompose problems, recognize patterns and apply algorithmic thinking in disaster scenarios. The spatial thinking component, which also consisted of eight questions, measured students' ability to interpret maps, analyze spatial relationships, and apply geographic information in a disaster context. The indicators of each indicator in the tes instrument are summarized in Table 3.

The test items were adapted from established computational and geographic education research frameworks. To ensure their validity, an expert review and content analysis were conducted, leading to necessary modifications based on expert recommendations. Additionally, Confirmatory Factor Analysis (CFA) was performed to validate the construct reliability of the test items. The outer loading values ranged between .811 and .841, indicating strong factor loadings for each indicator. Furthermore, the Average Variance Extracted (*AVE*) scores exceeded .50, confirming both convergent and discriminant validity of the instrument.

Prior to data collection, ethical approval was obtained from the respective school authorities. All participants were informed about the study's objectives, the confidentiality of their responses, and their voluntary participation. To adhere to ethical research principles, written consent was secured from all participants, ensuring that they understood their rights and the anonymity of their responses.

This methodological approach ensured that the instruments used in this study were both scientifically rigorous and ethically sound, allowing for a reliable assessment of students' digital literacy, disaster mitigation understanding, and cognitive skills related to computational and spatial thinking.

Table 2
The Statement of Each Indicator in The Structured Questionnaire

Indicators	Statements	Reference
DMU1	I understand the importance of disaster mitigation in reducing the impact of natural disasters	(Setiawati et al., 2022; Wahyono et al., 2022)
DMU2	I understand the different types of natural disasters that can occur in my region	(Ahmad et al., 2022; Prasetyo, 2022)
DMU3	I am aware of the different stages of disaster mitigation, including prevention, preparedness, response, and recovery	(Çalışkan & Üner, 2020)
DMU4	I am familiar with my community's disaster response plan	(Setiawati et al., 2022; Subekti et al., 2020)
DMU5	I understand the role of local government and emergency services in disaster mitigation	(Ekawati et al., 2022; Joakim & Doberstein, 2013)
DMU6	I understand the role of technology and innovation in enhancing disaster mitigation efforts, such as the use of GIS, remote sensing, and digital tools	(Ariyachandra & Wedawatta, 2023; Jiang, 2022)

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Indicators	Statements	Reference
DL1	I can effectively search for and evaluate information related to disaster mitigation from online sources	(Asteria, 2023)
DL2	I can critically analyze the credibility and reliability of disaster-related information shared on social media	(Asteria, 2023)
DL3	I can understand and interpret data visualizations (e.g., maps, graphs) related to disaster risks and mitigation strategies	(Logayah, 2023)
DL4	I can use digital technologies (e.g., mobile apps, websites) to stay informed about early warning systems and emergency procedures for disasters	(Prananingrum, 2023)
DL5	I can use online resources to learn about the specific disaster risks and mitigation strategies relevant to my local area	(Nafi'ah, 2023)
DL6	I can use digital tools to simulate and model disaster scenarios to better understand mitigation strategies	(Zamroh et al., 2022)

Table 3
The Indicator of Each Item Variable in The Tes Instrument

Indicators	Competence	Reference
CT1	Students are able to identify natural disaster problems faced by the community and formulate appropriate solutions to reduce the impact of disasters based on available data.	(Jairina et al., 2018)
CT2	Students are able to systematically organize steps or sequences of procedures for disaster mitigation (e.g. evacuation steps or handling after a disaster)	(Supiarmo et al., 2021)
CT3	Students can identify the most relevant information in the disaster mitigation process, such as focusing on important factors (e.g., geographical conditions, weather, and potential hazards)	(Supiarmo et al., 2021)
CT4	Students can detail the stages or steps of mitigation actions based on measurable or learnable components	(Supiarmo et al., 2021)
CT5	Students are able to collect and analyze disaster-related data (e.g., weather, topography, or population data) to support mitigation decisions	(Lawrence et al., 2020)
CT6	Students are able to recognize the relationship between natural disaster phenomena and other contributing factors (e.g., season, topography, or human activities).	(Supiarmo et al., 2021)
ST1	Students are able to read and understand topographic maps or maps of disaster areas.	(Charcharos et al., 2015)
ST2	Students are able to visualize disaster scenarios from map data or images, such as projecting the potential for flooding or the spread of forest fires	(Fischer et al., 2007; Lloyd, 2000)
ST3	Students understand the different scales on maps and can interpret distances or sizes accurately	(Kerski, 2008)
ST4	Students are able to rotate or project the rotation or change of orientation of objects on a map, for example, understanding how a stream of water or wind will move in a given situation	(Bednarz et al., 2007)
ST5	Students are able to identify spatial relationships between different objects in a disaster area, for example, how the distance between a volcano and a settlement affects the risk of eruption	(Astawa et al., 2022)
ST6	Students can explain the relative position between objects on the map, such as rivers, mountains, and settlements.	(Koch & Sheehan, 2014; Fischer & Sholl, 2008)

Data Collection

Data collection techniques were conducted systemically to ensure data validity and reliability. Data were collected using two research instruments consisting of a structured questionnaire and a performance-based test. These instruments were designed to assess students' digital literacy, disaster mitigation understanding, computational thinking, and spatial thinking ability. The structured questionnaire was used to measure students' digital literacy and understanding of disaster mitigation. Meanwhile, performance-based tests were used to measure students' computational and spatial thinking ability.

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Data collection was conducted in a controlled classroom under the supervision of researchers and trained teachers to minimize outside interference. Students were given a specific time allocation to complete the questionnaires and tests. The researchers gave clear instructions and answered any questions raised by the participants before the assessment began.

Data Analysis

Data analysis was conducted using Structural Equation Modeling (SEM) to test the hypothesized model and determine the strength of the impact between variables. This approach was chosen due to its effectiveness in establishing correlations and cause-and-effect relationships within educational research, particularly in disaster preparedness and literacy contexts (Cabuga & Cañete, 2023; Yildiz, 2023). Structural Equation Modeling (SEM) was used to analyze the collected data, testing the measurement models and structural impacts between digital literacy, disaster mitigation understanding, and computational and spatial thinking ability. Analyses began with confirmatory factor analysis (CFA) to verify the validity and reliability of the measurement model. Validity was assessed through outer loading (> .70), and reliability was evaluated through Cronbach's Alpha (> .70), Rho A (> .70), Composite Reliability (> .70), and convergent validity via *AVE* (> .50). Discriminant validity was examined using the Fornell-Larcker criterion, ensuring the square root of *AVE* (diagonal) for each variable exceeded other variable correlations, and by verifying that cross-loading values were highest within their respective constructs (Hair, 2019). Internal consistency values ranged from 0 to 1, with higher values indicating greater reliability. Path analysis was conducted to evaluate the direct and indirect effects of digital literacy and disaster mitigation understanding on computational and spatial thinking ability, as reflected in SEM regression weights. Bootstrap T and F statistical tests were performed using 5000 subsamples to determine the significance of path coefficients ($T > 1.96$, $p < .05$) at a 95% confidence interval (Hair, 2019).

Research Results

The Structural Equation Modeling (SEM) analysis revealed the strength of relationships between indicators and the measured latent variables: Computational Thinking (CT), Digital Literacy (DL), Spatial Thinking (ST), and Disaster Mitigation Understanding (DMU). Table 4 shows that all indicators have high outer loading values (ranging from .81 to .84), indicating strong contributions of each indicator to their respective latent variables. This confirms that the measurement model is valid and suitable for evaluating relationships among the latent variables in this study.

Table 4
Outer Loadings

Indicators	Computational Thinking	Digital Literacy	Spatial Thinking Ability	Understanding Disaster Mitigation
CT1	.83			
CT2	.81			
CT3	.83			
CT4	.83			
CT5	.84			
CT6	.84			
DL1		.82		
DL2		.83		
DL3		.83		
DL4		.82		
DL5		.84		

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Indicators	Computational Thinking	Digital Literacy	Spatial Thinking Ability	Understanding Disaster Mitigation
DL6		.83		
ST1			.83	
ST2			.84	
ST3			.84	
ST4			.84	
ST5			.81	
ST6			.83	
DMU1				.82
DMU2				.83
DMU3				.83
DMU4				.82
DMU5				.83
DMU6				.82

All latent variables—Computational Thinking (CT), Digital Literacy (DL), Spatial Thinking (ST), and Disaster Mitigation Understanding (DMU)—demonstrated excellent reliability, as evidenced by high Cronbach's Alpha (α) and Composite Reliability (*CR*) values. Additionally, the *AVE* values for all latent variables exceeded .5, confirming good validity (see Table 5). Thus, the evaluation of the measurement model for convergent validity was successfully fulfilled (Hair Jr. et al., 2021). The reflective measurement model displayed strong internal consistency, accurately measuring the latent variables.

Table 5
Construct Reliability and Validity

Variables	α	ρ_a	*CR*	*AVE*
Computational Thinking	.910	.910	.930	.690
Digital Literacy	.907	.907	.928	.682
Spatial Thinking	.910	.910	.930	.690
Disaster Mitigation Understanding	.906	.906	.927	.680

Table 6 presents the evaluation of discriminant validity using the Fornell-Larcker Criterion. The values in bold represent the square root of *AVE*, while the other values represent the correlation coefficients between constructs. Each construct's square root of the *AVE* was greater than its correlations with other constructs, indicating robust discriminant validity. The *AVE* square root values for Computational Thinking (.83), Digital Literacy (.83), Spatial Thinking (.83), and Understanding Disaster Mitigation (.82) confirm that each construct is distinct and free of overlapping variables. Thus, the discriminant validity evaluation based on the Fornell-Larcker Criterion is acceptable.

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Table 6
Discriminant Validity (Fornell-Larcker Criterion)

Variables	Computational Thinking	Digital Literacy	Spatial Thinking	Disaster Mitigation Understanding
Computational Thinking	**.83**			
Digital Literacy	.91	**.83**		
Spatial Thinking	.91	.91	**.83**	
Disaster Mitigation Understanding	.91	.92	.91	**.82**

Table 7 provides the cross-loading results between indicators and their corresponding latent variables. The indicators displayed the highest loadings on their intended latent variables compared to other latent variables, indicating that each construct strongly measures its respective domain. This further confirms the adequacy of discriminant validity, with variables more closely related to their main constructs than to others.

Table 7
Indicator Cross-loading

Indicators	Computational Thinking	Digital Literacy	Spatial Thinking	Disaster Mitigation Understanding
CT1	.83	.76	.76	.74
CT2	.81	.76	.74	.74
CT3	.83	.75	.77	.77
CT4	.83	.74	.77	.75
CT5	.84	.77	.74	.76
CT6	.84	.77	.76	.76
DL1	.74	.82	.76	.76
DL2	.75	.83	.73	.75
DL3	.77	.83	.76	.76
DL4	.75	.82	.75	.75
DL5	.74	.84	.75	.77
DL6	.77	.83	.75	.75
ST1	.78	.76	.83	.74
ST2	.76	.78	.84	.78
ST3	.75	.76	.84	.76
ST4	.76	.73	.84	.75
ST5	.74	.76	.82	.75
ST6	.76	.74	.83	.75
DMU1	.75	.77	.74	.85
DMU2	.74	.77	.77	.83
DMU3	.76	.75	.74	.83
DMU4	.73	.77	.76	.82
DMU5	.74	.74	.75	.83
DMU6	.76	.75	.76	.82

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The results of hypothesis testing, path coefficients, and item loadings for the research variables are summarized in Table 8 and illustrated in Figure 2. Hypothesis testing demonstrated significant relationships between all variables, with *p-Values* of .00 for all tested paths, indicating statistically significant effects. The path coefficients reveal the following:

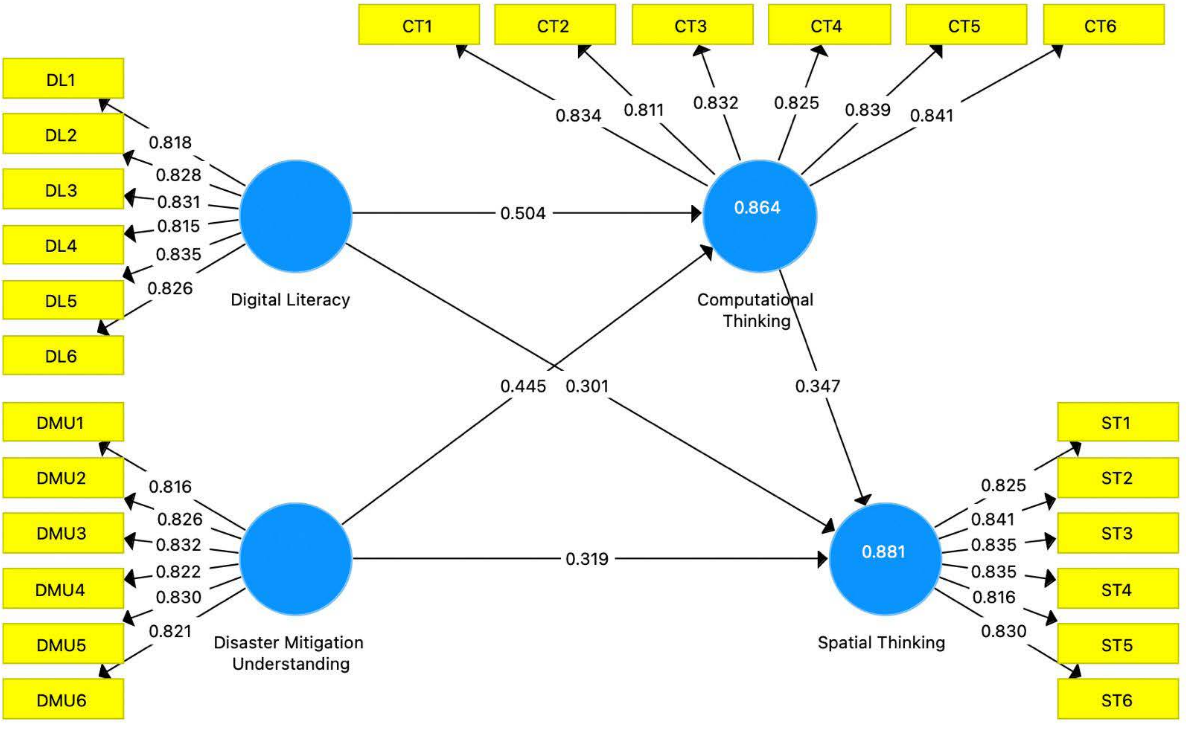
- Computational Thinking positively impacted on Spatial Thinking, with a coefficient of .35.
- Digital Literacy positively impacted on Computational Thinking (coefficient: .50) and Spatial Thinking (coefficient: .48).
- Understanding Disaster Mitigation affects Computational Thinking (coefficient: .45) and Spatial Thinking (coefficient: .47).

Moreover, high item loadings confirm that the variables consistently and strongly measure their respective latent constructs. Collectively, these findings support the hypotheses that digital literacy and disaster mitigation understanding significantly impact computational and spatial thinking ability. These results highlight the critical role of enhancing digital literacy and disaster mitigation understanding in fostering essential cognitive skills.

Table 8
Hypothesis Testing Results (Path Coefficients and Significance Levels)

Path (Hypothesis)	β	*M*	*SE*	T-Statistic (|β/SE|)	*p-Value*	Significance
H_1: DMU → CT	.45	.44	.06	7.63	< .01	Significant
H_2: DMU → ST	.47	.47	.05	8.84	< .01	Significant
H_3: DL → CT	.50	.50	.06	8.57	< .01	Significant
H_4: DL → ST	.48	.48	.05	8.85	< .01	Significant
H_5: CT → ST	.35	.35	.05	6.47	< .01	Significant

Figure 2
SEM Analysis Results



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Discussion

The findings of this study revealed significant interconnections between digital literacy, disaster mitigation understanding, and the development of computational and spatial thinking ability in upper secondary school students. Digital literacy significantly enhanced computational thinking ($\beta = .504$, $p < .001$) and spatial thinking ($\beta = .476$, $p < .001$). Similarly, disaster mitigation understanding had a substantial positive impact on computational thinking ($\beta = .445$, $p < .001$) and spatial thinking ($\beta = .473$, $p < .001$). These findings underscore the transformative potential of integrating digital literacy and disaster education into curricula. Additionally, computational thinking skills significantly contributed to spatial thinking ($\beta = .347$), indicating a synergistic relationship between these cognitive domains.

The findings align with existing literature that highlights the importance of digital literacy and disaster education in enhancing cognitive abilities. For example, Koçak and Göksu (2020) and Nurwahidah et al. (2021) demonstrated that digital literacy promotes computational thinking through algorithmic reasoning and problem-solving. Research by Wahyu et al. (2023) emphasized the role of spatial thinking in disaster preparedness, enabling effective analysis and interpretation of geographic data. However, this study advances the field by quantitatively elucidating the interactions among these variables through structural equation modeling (SEM). Compared to prior research, it offers deeper insights into how digital literacy and disaster education collectively shape spatial and computational cognition, an area previously underexplored.

The study's findings have significant implications for educational practices and curriculum design. By demonstrating that digital literacy and disaster mitigation understanding directly enhance critical cognitive skills, the study underscores the importance of embedding these components into educational strategies. Such integration equips students with the ability to tackle complex, real-world challenges, including disaster response and technological problem-solving. The positive correlation between computational and spatial thinking ability indicates that enhancing one domain can indirectly benefit the other, providing educators with a framework for interdisciplinary approaches. These results are particularly relevant for fostering 21st-century skills, resilience, and informed decision-making in students.

The findings are consistent with theoretical frameworks emphasizing the interconnectedness of cognitive skills, as highlighted in constructivist and systems thinking theories. Constructivist approaches advocate active learning, where digital literacy fosters problem-solving and knowledge construction through technology (Kesici, 2022). Similarly, systems thinking supports spatial cognition by enabling learners to model and interpret complex relationships within disaster scenarios (Hasnawiyah, 2024). The study also builds on research demonstrating the efficacy of Geographic Information Systems (GIS) and simulation-based learning in disaster education, which simultaneously enhance spatial reasoning and preparedness (Logayah, 2023; Wahyu et al., 2023).

While this research effectively addresses its primary objective by examining the impact of digital literacy and disaster mitigation education on computational and spatial thinking ability, some limitations must be acknowledged. First, this study employed a cross-sectional design, which limits the ability to establish causality over time. Future research should consider a longitudinal approach to better understand the long-term effects of digital literacy and disaster education on cognitive skill development. Additionally, socio-cultural factors may influence students' engagement with digital literacy and disaster education, suggesting a need for further research into contextual variables.

Despite these limitations, this study makes a significant contribution by offering empirical evidence on how integrating digital literacy and disaster mitigation education can enhance computational and spatial thinking ability. The findings support the growing body of literature advocating for interdisciplinary approaches to education that prepare students for complex problem-solving in the digital age. Future studies should explore additional instructional strategies, such as game-based learning and virtual reality simulations, to further enhance students' cognitive skills in disaster preparedness and digital literacy.

Conclusions and Implications

This study has provided empirical evidence that the integration of digital literacy and disaster mitigation education significantly enhances students' computational and spatial thinking ability. The findings indicate that digital literacy positively impacted computational thinking and spatial thinking. Similarly, disaster mitigation understanding contributes to the improvement of computational thinking and spatial thinking. Furthermore,

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computational thinking demonstrates a direct impact on spatial thinking, suggesting an intrinsic relationship between these cognitive abilities.

These findings underscore the importance of integrating digital literacy and disaster mitigation education into formal curricula as a means of fostering students' cognitive competencies in a technology-driven world. The empirical evidence supports the necessity of interdisciplinary learning models that incorporate both digital and disaster-related knowledge, equipping students with essential problem-solving and analytical skills required for contemporary global challenges.

From an educational perspective, the results highlight the need for curriculum innovation that integrates digital technologies and disaster preparedness into secondary education. The incorporation of digital tools, such as Geographic Information Systems (GIS) and simulation-based learning platforms, can enhance students' analytical abilities and disaster response competencies. Additionally, teacher professional development programs should emphasize pedagogical strategies that utilize digital literacy as a vehicle for enhancing disaster education.

From a policy standpoint, educational institutions and policymakers should prioritize the integration of interdisciplinary approaches in curriculum development, particularly in regions vulnerable to natural disasters. The adoption of digital literacy and disaster education can serve as a proactive measure in cultivating a generation of students equipped with the necessary cognitive and practical skills to navigate disaster-prone environments effectively.

For future research, longitudinal studies are recommended to examine the sustained impact of digital literacy and disaster mitigation education on students' cognitive skill development. Additionally, further research should explore the impact of socio-cultural factors on students' engagement with digital and disaster-related learning. Experimental studies may also be conducted to compare the effectiveness of various instructional methods, such as gamified learning, augmented reality, and collaborative problem-solving approaches, in fostering computational and spatial thinking ability.

This study provides empirical evidence supporting the integration of digital literacy and disaster mitigation education as a means of strengthening students' cognitive abilities. By fostering computational and spatial thinking, such interdisciplinary approaches can better prepare students to navigate complex, technology-driven challenges and contribute to disaster-resilient communities. Future research should continue exploring innovative educational strategies to enhance student preparedness, resilience, and analytical skills in addressing global challenges.

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Declaration of Interest

The authors declare no competing interest.

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